Survey on Flood detection and Forecasting

Using Wireless Sensor Networks

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***Abstract*— In this survey paper , various types of sensors used in wireless sensor networks (WSN) for flood detection and forecasting, architectures and instrumentation in various WSN for flood detection , the communication strategies used to establish the links and parse the data and queries inside the WSN and to the external sink are studied. Typical challenges faced in routing and data transmission and retrieval with respect to energy issues and external factors and the various factors that affect the WSN are also mentioned.**

Keywords— Flood detection and forecasting, Wireless Sensor Networks, Architecture ,Sensors

I. INTRODUCTION

Being the most frequent and widespread natural disaster, flood is scenario where large volumes of water enter an area that cannot be drained off through conventional channels. It takes long time to overcome the prolonged ill effects of the floods. Besides being a natural disaster , the man made activities like deforestation ,recovering land from river banks and catchment areas have increased the effects of the floods.

The cause of floods can be various reasons like heavy rains , high winds ,cyclones ,storms , tsunami , melting snow caps or dam bursts etc...,no matter what be the cause they leave extensive damage to property and infrastructure and sober for thousands of people. Types of Floods include slow floods and flash floods[1]. Slow floods arise due to increase of the river water levels gradually over a period of time . On the other hand Flash floods occur quickly and without prior warning .In this paper we deal with wireless sensor networks for detection and forecasting the flash floods .Various hydrological and structural measures were implemented over years for flood forecasting and monitoring, but the results were limited as the sensors used in these systems are not actually located in the flood prone zones, which reduces the accuracy, depedancyon these systems.

With the advent of technological advancements like wireless communication, Micro Electro Mechanical Systems (MEMS) and Very Large Scale Integration (VLSI) we now can afford for a new kind of monitoring system .Wireless Sensor Networks(WSN) can be deployed very close to these flood prone zones and can be operated with minimum possible human interference .

The next section deals with the deployment areas, external factors to be considered during the design of these network systems. In the following section we study the instrumentation, hardware and architecture used in any wireless sensor networks and more specific to flood detection and forecasting networks. The section IV of this paper deals with the sensors used in the wireless sensors networks and various issues related to these sensors. In section V, study of various communication strategies are given. The section VI deals with data retrieval and challenges faced due to the external factors, effectiveness of the networks. Finally we conclude the paper with future ways to overcome the drawbacks in the current systems and improve them.

II. DEPLOYMENT OF NETWORK

The river basins banks and coastal areas are home to many people . When a flash flood or hurricane occurs , it breaches the areas along ,killing many people. The best example of this was the Indian Ocean Tsunami of 2004, when many were swept into the ocean without warning. The WSN based flood detection systems are deployed in under developed countries where the expensive flood warning systems which rely on expert hydrologists who monitor real time data 24 hours a day and run sophisticated computational models at centralised stations are not available as in developed countries.

Most of the recent flood forecasting systems are WSN based [7],[8],[9].From [4], it is vivid that the WSN used for any application can be of three types : Centralised , distributed, Hybrid models. A centralized model is one where computation occurs at the central node only. A distributed model is one with computations at various levels instead of only one computing node. Hybrid model comprises of the centralized model and part of the distributed model. The extent to which a part of each model may vary as per application. The deployment of the network is based on the type of model being used. The deployment can also be static as in [7] and sensors feeding data offline. This mini-grid based system allows wide range of target deployments by selectively combining component frameworks, either rich and complex, or basic and simple, as appropriate. By removing unnecessary components in this way, and thus reducing the associated computation and storage requirements. Unlike other systems [9] is deployed after occurrence of flood to detect the impact level. The system proposed in [9] is basically for real-time tracking of path, and speed of flood water . The network is made of low cost disposable , floating micro sensors which are released into flood waters.

The WSN are deployed along the river banks , basins & coastal areas. The Network can be sparse if it used only for detecting the flood and warning purposes. But the same requires a dense network if the forecasting, course of the flood water, intensity and speed of the same are to be measured.

III. INSTRUMENTATION,HARDWARE & ARCHITECTURE

The basic architecture of any WSN is as shown in figure 1.

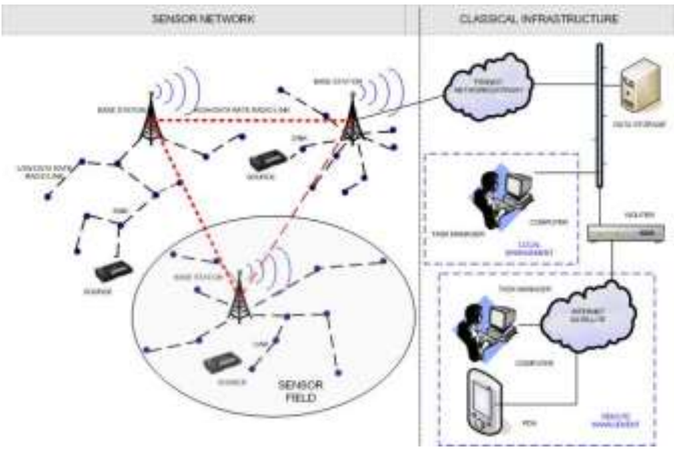

Figure 1 .Illustration of sensor network and backbone infrastructure.

A. *Communications/hardware Architecture for Wireless Sensor Networks.*

The components that constitute for the architecture are :

- The Sensor nodes that form the sensor network, to make discrete, local measurement about surrounding environment, forming a network, and collect & route back the data.
- The sink/computation node, which has more processing capabilities and energy reserved, communicates with the user and is located near the field . Data is routed to sink by multi-hope communication from the sensor nodes.
- Event of interest, for which the sensing nodes will be monitoring.
- And the user.

B. *Design Factors and Requirements.*

Many design factors have to be addressed while designing a WSN. These are listed as follows:

- Reliability
- Density and Network size/scalability
- Network topology,
- Energy constraints,
- Hardware constraints ,
- Data aggregation/Fusion ,
- Transmission media,
- Security, Coverage,
- Self -Configuration,
- Network dynamics,
- Quality of Service,
- Connectivity,
- Environment of operation.

But for flood detection and forecasting specific application the requirements are as follows[6]:

- Monitor events over large geographic regions of approximately 10,000 km2
- Measure a wide variety of variables contributing to the occurrence of the event
- Survive long-term element exposure (on the order of years)
- Recover from node losses(adaptable to topological changes)
- Detect and predict the river flood
- Withstand the river flood
- Power system for years
- Minimize costs
- Handle significant computation requirements

All above parameters have to be considered and the design has to be optimised according to the application.

For flood detection and forecasting WSN, the major design issues are to maintain the network connectivity, topology which will be effected by floods apart from normal energy depletion.

C. *The architecture of protocol stack*

The protocol stack consists of physical layer, data link layer, network layer, transport layer, application layer, power management, and task management.

The system proposed in [4,7] uses a hierarchical architecture with sensing nodes, computation nodes possessing powerful CPUs to implement the prediction model, and monitoring station like in many other WSN. The computation node is responsible for data aggregation and transmitting the same to monitoring station. Unlike the system in [4] ,the one in [7] uses a mini-grid based computational model, with part of the computation done at the monitoring station and the rest at the nodes. This leads to creation of sub networks inside the WSN. The kit used in [7] is based on 'Gumstick' hardware platform and 'Gridstix' software, achieves a trade-off between computational resources and power consumption. Each mote in [7] features an Intel XScale CPU running at up to 400MHz, and comes equipped with 64MB of RAM, 16MB of flash memory and Bluetooth radio, which makes them handle part of computation. The sensors used in [9] transmit the speed and path of flood water to the wireless network attached to the light posts of the city, which are part of the city's smart city platform's plan. It features low-cost, environmentally friendly, mass-produced microsensors .So this comes under hybrid model system of WSNs.

IV. SENSORS

A. Traditional sensors

Flash floods occurrence can be predicted by observing various cloud patterns in atmosphere. Therefore, the commonly used input data set for these kind of telemetry based systems are taken from the meteorological satellites like polar orbiting NOAA series, and Geostationary satellites(GMS,METEOSAT, GOES)[3].

B. Wireless sensors networks based sensors

In the case of a WSN deployed for flood forecasting, the sensors and the data sets are completely different. Sensor nodes are the network components that will be sensing and delivering the data. Based up on the routing algorithms used, sensor nodes will instigate transmission according to measures and/or a query originated from the Task Manager/sink/base station.

Different types of sensors are required to sense water discharge from dam, rainfall, humidity, temperature, which directly or indirectly may lead to flood[4]. In this system a time set is used instead of a specific interval for sensing. In the data-driven statistical flood-prediction models, details of the landscape, soil composition, and land cover, along with atmospheric conditions and hydro-meteorological measurements like soil moisture are required [7,9] .So these tasks require various corresponding sensing capabilities also in the network. In [9], the KAUST-developed microsensors are inexpensive, disposable, waterproof, and require no special protection to operate in debris-filled flood waters for flood course identification.

V. COMMUNICATION STRATEGIES

A. MAC Protocols

MAC protocols control how sensor nodes access a shared radio channel to communicate with neighbours. Traditionally, this problem is known as the channel allocation or multiple access problems. The design of MAC protocols in wireless sensor network depends on the expected traffic load patterns in the application context. In case of flood forecasting and detection WSN systems simple Sensor Medium Access (S-MAC) Protocol would do suffice. The sleep wake cycle can be adjusted based on the time and surroundings and previous predictions[11]. Guaranteed Time Slots can be allotted to specific nodes of interest . Beacon enabled structures are preferred as the network would be sparse and distantly spread out to synchronisation.

B. Routing

Routing algorithms are as important in WSN as the Architecture and hardware. Proper routing techniques reduce the energy consumption of the WSN by reducing communicating cost. In case of flood detecting WSNs the geographical area covered by the WSN is quite large and the density of the motes deployed is sparse. This pertains to the fact that the if flash floods occur in an area then ,few motes are enough to detect and alarm the personal , and also deploying too many motes would simply mean increase the cost, bandwidth utility. Most of the flood detecting and forecasting WSNs use a combination of both geographical and information driven routing rotocols[6,11].

The system in [6] uses a separate protocol ,ALERT protocol, that defines data structures and policies of environmental monitoring systems[8].It also allows the system to alert the local system to alert through TV & radios directly.

VI. DATA RETRIEVAL AND CHALLENGES FACED

A. Data retrieval

The algorithm presented in [4] uses an event driven system ,where event are sudden change in a parameter affecting conditions. But a hardware interrupt has also been provided to override the time driven mechanism to get an instant event driven data and make a reliable prediction before the flood occurs. A hardware interrupt is used in [4] to get the instant query driven data. Sampling rate may be increased during peak times like cyclones or hurricanes. The mini-grid based system described in [7] can adapt itself according to the conditions, and the uses 802.11b or Bluetooth to transmit the data based on the size of the data. It switches between these two base on required range of transmission ,which in turn is based on current topology. Initially Bluetooth is used , but as motes die out , network switches to 802.11b to increase the range of each mote.

B. External factors and Challenges

Other interrupts include to identify corruption or loss of data during any phase of the communication process-data sensing or recording, transmission, accumulation or calculation[4]. While measuring flood levels is relatively easy with remote level sensors, measuring actual flood water velocity is more complex and expensive, since flood water is typically dirty and contains much debris. Mechanical, laser-based, and acoustic flow sensors are expensive and prone to issues such as clogging and breaking due to encounters with debris[9].The micro sensors used are resistant to these kind of damaages.

C. Effectiveness of the system

The computational nodes transmit sensed information and also their own predictions to the monitoring station. The station reruns the algorithm and generates the alert if needed. [4]. The computational nodes are provided with previous data needed to standardize the coefficients and this happens by live transfer of data in network[4]. Choosing threshold level is very critical as it may lead to unnecessary false alarms. The mini gird system consumes about 1 watt/hour , higher than the Berkley mote's consumption ,that is accurate detection and in network computation are achieved at the cost of energy. The system in [9] do not require manual release or central coordination of microsensors. It links with other Smart City technologies and provides detailed, real-time data during dynamic flooding conditions, enabling accurate reporting and predictive modelling .

VII. CONCLUSION

A key part of any WSN is to obtain the tradeoff between controlling costs and increasing the accuracy and computation capabilities of the system. WSN deployment is cheaper than many flood detecting systems, still the costs remain high. For instance based on the research work conducted by MIT researchers , the initial prototype cost of motes was 200$ per mote, up on economies of scale it went down to 50$ per mote and can be further reduced to 10$ per mote[10].But at the same time we need to optimize the accuracy ,reliability of the systems. Routing protocols for sparse network along the curve should be developed .At the end obtaining maximum possible optimal gain from system marks the success of the complete systems.

VIII. TABLES

Figure 1	"Walsaip research project"- technical report tr-ncig-0501, Miguel Angel ,Erazo Villegas, Seok Yee Tang,Yi Qian, Department of Electrical and Computer Engineering,University of Puerto Rico at Mayagüez.

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